US Army Corps
of Engineers®

TI 810-10
1 February 1999

Technical Instructions

MECHANICAL DESIGN
HEATING, VENTILATING, AND
AIR CONDITIONING

Headquarters
U.S. Army Corps of Engineers
Engineering Division
Directorate of Military Programs
Washington, DC 20314-1000

TECHNICAL INSTRUCTIONS

MECHANICAL DESIGN
HEATING, VENTILATING, AND
AIR CONDITIONING

Record of Changes (changes indicated \1\ . . . /1/.)

No.	Date	Location

FOREWORD

These technical instructions (TI) provide design and construction criteria and apply to all U.S. Army Corps of Engineers (USACE) commands having military construction responsibilities. TI will be used for all Army projects and for projects executed for other military services or work for other customers where appropriate.

TI are living documents and will be periodically reviewed, updated, and made available to users as part of the HQUSACE responsibility for technical criteria and policy for new military construction. CEMP-ET is responsible for administration of the TI system; technical content of TI is the responsibility of the HQUSACE element of the discipline involved. Recommended changes to TI, with rationale for the changes, should be sent to HQUSACE, ATTN: CEMP-ET, 20 Massachusetts Ave., NW, Washington, DC 20314-1000.

TI are effective upon issuance. TI are distributed only in electronic media through the TECHINFO Internet site *http://www.hnd.usace.army.mil* /techinfo/index.htm and the Construction Criteria Base (CCB) systems maintained by the National Institute of Building Sciences at Internet Site *http://www.nibs.org/ccb/*. Hard copies of these instructions produced by the user from the electronic media should be checked against the current electronic version prior to use to assure that the latest instructions are used.

FOR THE COMMANDER:

DWIGHT A. BERANEK, P.E.
Chief, Engineering and Construction Division
for Military Programs

MECHANICAL DESIGN
HEATING, VENTILATING, AND
AIR CONDITIONING

Table of Contents

Table of Contents (continued)

Page

Table of Contents (continued)

Page

TABLES

CHAPTER 1

INTRODUCTION

1-1. PURPOSE AND SCOPE. This document provides guidelines for design of heating, ventilating, and air conditioning (HVAC) mechanical systems. This document delineates only those features of HVAC design that are unique in their applications, or reflect policies that have been established through regulations, directives, and other published media through the Department of Defense. Unless otherwise specified, all designs will comply with the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbooks and Military Handbook 1008C.

1-2. APPLICABILITY. These instructions apply to all elements responsible for military construction design.

1-3. REFERENCES. Appendix A contains a list of references used in these instructions.

1-4. BASIC PRINCIPLES. The designer will base all designs on the following basic principles:

a. Interior design conditions selected, including temperature, humidity, filtration, ventilation, air changes, etc., will be suitable for the intended occupancy.

b. System selections will conform to the life cycle cost criteria and energy targets specified in the Architectural and Engineering Instructions (AEI). The designer will evaluate all energy conservation items that appear to have potential for savings, such as heat recovery for HVAC and service water heating, economizer cycles, thermal energy storage, desiccant dehumidification, plastic door strips for load docks, etc., and include those items in the design that are life cycle cost effective.

c. To the maximum extent possible, designs will incorporate all practical energy sources and design features that conserve natural resources and are environmentally friendly. This emphasis has recently become known as “sustainable designs.”

d. The design will be as simple as possible.

e. Adequate space to access items that require maintenance, such as filters, coils and drain pans, and strainers, will be provided. Where possible, include a representative of the customer’s facility maintenance staff as part of the design review team who can provide input regarding the maintainability of the HVAC design.

f. Systems with the features necessary for successful testing, adjusting, and balancing and for easy access for maintenance will be provided.

1-5. WAIVERS. Where a valid need exists and an alternate solution involving sound engineering is available, designers can submit requests for a criteria waiver to HQUSACE (CEMP-ET), Washington, DC 20314-1000. Requests for waiver must include justification, life cycle cost analysis, criteria used, and other pertinent data.

1-6. REDUNDANT SYSTEMS. Generally, redundant HVAC systems are not required. However, when a system failure would result in unusually high repair costs or replacement of process equipment, or when activities are disrupted that are vital to national security, the designer may submit a request for approval to HQUSACE in accordance with paragraph 1-5 to provide redundant HVAC systems. No waiver is required where redundant HVAC systems are specified by other applicable criteria.

CHAPTER 2

FUNDAMENTALS

2-1. CALCULATIONS.

a. Heating Load Calculations. Exclude anticipated internal and solar heat gains from heating load calculations. Increase the calculated size of equipment and distribution system by up to 30 percent where necessary to compensate for morning recovery due to night setback.

b. Cooling Load Calculations. Prepare cooling load calculations using either the transfer function method (TFM) or the CLTD/SCL/CLF Method, which is based on the cooling load temperature differences (CLTD), the solar cooling load factors (SCL), and the cooling load factors (CLF). These methods are described in the ASHRAE Handbook Fundamentals. If necessary, increase the calculated size of equipment and distribution system(s) by up to 10 percent to compensate for morning recovery due to night set forward or by up to 10 percent to compensate for unanticipated loads or changes in space usage. Limit the total combined increase above the size calculated of equipment and distribution system(s) to 15 percent total. Submit a psychometric plot of each air-conditioning system along with the calculations. Clearly identify all points in the conditioning process on the psychrometric chart and verify both sensible, latent, and total capacity using the appropriate data from the chart. List the sensible, latent, and total capacity requirements for each cooling coil specified. For applications where reheat is required for humidity control, the capacity of the reheat will be equal to the total internal sensible heat generated in the area served.

2-2. DESIGN CONDITIONS.

a. Outdoor Design Conditions.

(1) The outdoor design temperature for comfort cooling will be the 2.5 percent dry bulb and the corresponding mean coincident wet bulb temperature as listed in TM 5-785. Base the selection of evaporative equipment on the 2.5 percent wet bulb temperature. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may use the corresponding 1.0 percent temperatures. For the selection of condensers and condensing units that will be subjected to unusually high radiation heat grain, add 3 degrees C (5 degrees F) to the dry bulb temperature specified above.

(2) The outdoor design temperature for comfort heating will be the 97.5 percent dry bulb temperature as listed in TM 5-785. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may substitute the 99.0 percent temperature for the 97.5 percent temperature.

b. Indoor Design Conditions.

(1) The indoor design temperature for comfort cooling will be 8.3 degrees. C (15 degrees. F) less than the 2.5 percent outdoor design temperature, but will not be lower than 23.9 degrees C (75 degrees F) or higher than 25.6 degrees C (78 degrees F). The indoor design specific humidity will not exceed the outdoor design specific humidity; otherwise, the indoor design relative humidity will be 50 percent. The indoor design temperature provided by evaporative cooling or comfort mechanical ventilation will be 26.7 degrees C (80 degrees F).

(2) The indoor design temperature for comfort heating will be 20 degrees C (68 degrees F) in areas with low levels of physical activity and 12.8 degrees C (55 degrees F) in areas with moderate to high levels of physical activity. The indoor design temperature for freeze protection will be 4.4 degrees C (40 degrees F). Where the indoor relative humidity is expected to fall below 20 percent for extended periods, humidification may be added to increase the indoor relative humidity to 30 percent.

2-3. INFILTRATION. Design air distribution systems for central HVAC systems to maintain a slightly positive pressure within the area served in order to reduce or eliminate infiltration unless there is a valid need to maintain a negative pressure in that area.

2-4. VENTILATION. Ventilation will be in accordance with ASHRAE Standard 62.

a. Provide a complete ventilation analysis in each HVAC design analysis. The ventilation analysis will consist of a room-by-room breakdown of the anticipated number of occupants, the amount of ventilation air required, and any applicable adjustments such as multiple spaces factor, intermittent or variable occupancy factor, flow reduction factor, and ventilation effectiveness factor. Where these adjustments are significant, explore design alternatives to reduce life cycle costs. Ventilation for variable air volume systems will ensure proper ventilation rates at low and high system airflow.

b. Provide a ventilation schedule on the drawings, perhaps combined with the diffuser/register schedule. This schedule should assist the building occupants when performing future renovations. List the total supply air and the number of anticipated occupants for each room in the schedule. Add a footnote to each schedule indicating that the number of occupants listed is for information purposes only.

c. Locate outdoor air intakes in areas where the potential for air contamination is lowest. Basic guidelines include the following:

(1) Maximize distance between intakes and cooling towers, plumbing vents, loading docks, traffic, etc.

(2) Maintain a minimum distance of 10 meters (30 feet) between intakes and exhausts, more if possible.

(3) Locate intakes and exhausts on different building faces.

d. Where desirable, the designer may incorporate a purge mode into system design. This mode could be used, for example, to purge the building with outside air during off-hours or to purge an area of the building undergoing maintenance, such as painting.

e. Where practical, locate photocopiers and laser printers in a separate room or group them together and provide local exhaust. Maintain the separate room at a negative pressure relative to adjacent areas by transferring air from these adjacent areas to the separate room. Do not add the air exhausted from the separate room or local exhaust to the return air or transfer it to any other areas.

2-5. FILTRATION. For administrative facilities, commercial facilities, and similar occupancies where indoor air quality is of primary concern, filter the combined supply air, including return and outside air, using a combination of 25- to 30-percent efficient prefilter(s) and 80- to 85-percent efficient final filter(s) as determined by the dust spot test specified in ASHRAE Standard 52. Where practical, provide separate filtration or other means to clean the outdoor air, typically equivalent to that used for the combined air stream, prior to mixing it with the return air. Separate filtration for the outdoor air will reduce the contaminants in the outdoors from entering the primary air stream. Even in areas where the outdoor air is seemingly clean, low levels of auto-emissions, pollen, dust, etc., can accumulate on the interior of ductwork and plenums and later cause inadequate air quality problems. Due to the decrease in system airflow as the pressure drop across the filter increases, size fans for the “dirty” filter condition. This will ensure that each fan has adequate capacity to deliver the design airflow as the filter becomes loaded.

2-6. DUCT DESIGN.

a. Use either the Static Regain or the T-Method method to design ducts for VAV systems. Use round or oval prefabricated duct where feasible. Round/oval prefabricated duct reduces leakage and friction losses, which correspondingly reduces the amount of conditioning and fan energy used. The additional material cost for round/oval prefabricated duct is often offset by reduced installation cost and time.

b. Ensure that duct design incorporates all features necessary to accommodate testing, adjusting, and balancing (TAB). For example, provide adequate length of duct, both upstream and downstream of fans and coils. Show the necessary fittings, transitions, test ports, etc. required for successful TAB, for duct inspection and cleaning, and for damper access and inspection.

c. Do not use the following types of construction where the potential for subterranean termite infestation is high:

(1) Sub-slab or intra-slab HVAC ducts.

(2) Plenum-type, sub-floor HVAC systems, as currently defined in Federal Housing Administration minimum acceptable construction criteria guidance.

(3) HVAC ducts in enclosed crawl spaces that are exposed to the ground.

(4) HVAC systems where any part of the ducting is in contact with or exposed to the ground.

2-7. RADON. Include the following features in designs for all new facilities to reduce the potential radon exposure to the facility occupants:

a. Seal all penetrations through foundation wall/slab in accordance with TM 5-805-6 or with prefabricated seals designed for the prevention of radon entry.

b. Design ventilation systems to maintain positive pressure within the occupied spaces where practical.

c. Include provisions for a sub-slab ventilation system in the design that may later be required to complete a system to maintain that area at a negative pressure of 1.25 to 2.50 cm water (0.5 to 1.0 inches water) column at the vent inlet in comparison to the occupied spaces. One method that has proven to be successful consists of a 10-cm (4-inch) diameter PVC suction pipe per each 150 m^2 (1500 ft^2) of slab area. Embed perforated pipe into the aggregate through the slab and cap the top of the pipe. These vent pipes can later be uncapped and attached to an exhaust fan if radon mitigation is required after construction. Provide access to air intake for areas isolated by footings or grade beams.

2-8. CONTROLS. Design HVAC controls in accordance with TM 5-815-3.

2-9. NOISE AND VIBRATION CONTROL. Design HVAC systems with respect to noise and vibration control in accordance with TM 5-805-4. Use acoustical duct liner only where other methods of noise control are not feasible.

2-10. SEISMIC PROTECTION. Design HVAC systems with respect to seismic protection in accordance with TM 5-809-10.

2-11. TESTING, ADJUSTING, AND BALANCING. CEGS 15990 contains many of the requirements of HVAC testing, adjusting, and balancing. CEGS 15990 contains strict quality control guidelines that the construction contractor must meet in order to verify that the HVAC systems have been properly installed and operating as specified. TAB considerations merit careful attention by the designer to ensure that the customer's needs are met. Few portions of a typical building require interaction by so many separate components under widely different operating conditions; therefore it is imperative that the designer address all aspects of TAB during the design.

2-12. COMMISSIONING. The use of CEGS 15995 is mandatory for all Air Force projects and its use is encouraged for all projects. Note that use of CEGS15995 requires funding for the designer or a representative of a designer to participate in the commissioning at the project site. Commissioning is intended for all appropriate contractor and customer (typically a representative of the Department of Public Works or the Base Civil Engineer) personnel and the designer to demonstrate that the HVAC systems have been properly installed and operate as intended by the designer and that the systems will satisfy the customer's. Another tangible benefit is that the customer has the opportunity to become familiar with the operation of the HVAC systems. Commissioning is not intended to be used in lieu of any tests specified by related CEGS.

2-13. REFRIGERANTS. Carefully review the current version of the appropriate CEGS prior to the selecting mechanical refrigeration equipment. Current and anticipated future restrictions limit or prohibit using ozone-depleting substances. All designs will comply with ASHRAE Standard 15, "Safety Code for Mechanical Refrigeration." Where refurbishment or demolition of mechanical refrigeration equipment is involved, provide detailed step-by-step guidance and diagrams that comply with the recommendations of ASHRAE Guideline 3 for this work.

2-14. SPECIAL CRITERIA FOR HUMID AREAS. Use the following criteria in the design of air-conditioned facilities located in areas—

- where the wet bulb temperature is 19.4 degrees C (67 degrees F) or higher for over 3,000 hours and the outside design relative humidity is 50 percent or higher, or

- where the wet bulb temperature is 22.8 degrees C (73 degrees F) or higher for over 1500 hours and the outside design relative humidity is 50 percent or higher, based on 2.5 percent dry bulb and 5.0 percent wet bulb temperatures.

a. Building Insulation. Ensure that the architect is aware that the vapor barrier should be installed outside the thermal envelope created by the insulation. Where ventilation is required outside of normally occupied spaces but within the thermal envelope, use transfer air from the occupied space as the source of the ventilation.

b. System Selection. HVAC systems will typically consist of a central air-handling unit with chilled water coils or a unitary direct expansion-type unit(s) capable of controlling the dew point of the supply air for all load conditions. In addition to life cycle cost considerations, the designer must base system selection on the capability of the air-conditioning system to control the humidity in the conditioned space continuously under full load and part load conditions. System selection will be supported by an energy analysis computer program that will consider the latent-heat gain due to vapor flow through the building structure, to air bypassed through cooling coils, and to the dehumidification performance of the air-conditioning system under varying external and internal load conditions. Peak latent load outdoor design conditions (the design wet bulb temperature and the mean-coincident dry bulb temperature) or low sensible loads and high latent loads (relatively cool cloudy days) will, in some cases, cause inside relative humidity to be higher than desired. If analysis indicates that this condition will occur, reheat will be used. Use recovered heat for reheat where possible. Do not use room fan-coil in humid areas, as they do not provide adequate dehumidification under many outdoor conditions.

c. Air Handling Units. Specify draw-through type air-handling units in order to use the fan energy for reheat. Design the air distribution system to prevent infiltration at the highest anticipated sustained prevailing wind.

d. VAV Systems: Use air throttling type VAV terminal units with an integral heating coil and a pressure independent air valve that modulates in response to space temperature.

e. Ventilation. Condition outdoor air at all times through a continually operating air-conditioning system. Consider using a separate system for outdoor air where necessary to maintain a sensible heat ratio of the mixed air entering the primary air-conditioning unit within the required limits of commercially available equipment or to reduce corrosive, salt-laden air from entering the primary air distribution system.

f. Air and Water Temperatures. Base the supply air temperature and quantity, and chilled water temperature on the sensible heat factor, coil bypass factor, and apparatus dew point.

g. Outdoor Design Temperatures. Use the one percent wet bulb temperature in cooling calculations and equipment selections.

h. Closets and Storage Areas in Air-conditioned Facilities. These areas should be either directly air conditioned or provided with exhausts to transfer conditioned air from adjacent spaces.

i. Reheat. Where reheat is required to maintain indoor relative humidity below 60 percent, consider heat recovery, such as reclamation of condenser, heat in life cycle cost analysis.

j. Economizer Cycle. Economizer cycles generally will not be used due to the high moisture content of outside air.

k. Penetrations of Conditioned Envelope and Thermal Bridging. Considerable moisture may enter the conditioned envelope both through penetrations for items such as pipes and conduits or as condensation as a result of thermal bridging at locations such as door and window frames and intersections of walls or walls and roofs. Provide details on the drawings for penetrations and potential thermal bridges.

2-15. WATER TREATMENT. The local water composition is essential to the design of water treatment for mechanical systems. A water analysis may be available from the using agency. If an analysis is unavailable, obtain a sample of the raw water. Test the sample and include the results in the applicable contract specifications. Design water treatment systems for boilers in accordance with TM 5-650. Provide water treatment systems for cooling towers for prevention of corrosion, scale, and biological formations. In most cases, a water treatment is required for closed chilled-water systems, hot water systems, and dual-temperature systems.

CHAPTER 3

SYSTEMS

3-1. SYSTEM SELECTION. Chapter 3 provides guidance regarding the eligibility of a facility for air conditioning, dehumidification, evaporative cooling, mechanical ventilation, or heating.

3-2. HEATING SYSTEMS. Use steam or high-temperature water for large distribution systems.

a. Steam. Do not use single-pipe systems. For safety purposes, use low-pressure steam [100 kPa gage (15 psig) and below] where terminal equipment is installed in occupied areas. High-pressure steam [above 100 kPa gage (15 psig)] unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 4 meters (13 feet) above floor level.

b. Hydronic Systems.

(1) Do not use gravity flow hot-water systems.

(2) For safety purposes, use low-temperature hot water [120 degrees C (250 degrees F) and below] where terminal equipment is installed in occupied areas. Medium-temperature hot water [120 to 175 degrees C (350 to 420 degrees F)] or high-temperature hot water [175 to 200 degrees C (350 to 400 degrees F)] unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 4 meters (13 feet) above floor level.

(3) Provide for freeze protection by either automatic operation of circulating pumps when outside temperature drops below 2 degrees C (35 degrees F) or by the addition of an appropriate antifreeze solution. The designer should provide adequate calculations to ensure that freeze protection is sufficient for the extreme outdoor conditions encountered. The methodology used for determining the extreme outdoor condition in the ASHRAE Handbook Fundamentals may be used where appropriate.

c. Warm Air. Do not use gravity flow warm air furnaces. Direct-fired heaters are prohibited in areas subject to hazardous concentrations of flammable gas, vapors, or dust.

d. Infrared Radiant Heating. Consider infrared radiant heating for high-bay areas or where spot heating is required. Gas, oil, and electricity may be considered as fuel sources. Use night setback where it is both appropriate and cost effective.

e. Floor Radiant Heating Systems. Use hot water temperatures less than 50 degrees C (125 degrees F)]. Due to this low temperature, the designer will provide a control system to maintain the recommended water temperature for the boiler. Night setback control will not be used for high-mass floor systems. The designer will coordinate closely with the architect and structural engineer concerning floor insulation, floor coverings, floor load bearing characteristics, and manifold access.

f. Electric Resistance Heating. Do not use electric resistance heating except under the conditions outlined herein:

(1) Family Housing. Electric resistance heating may be used where a bathroom has been added and the existing heating system is inadequate to heat the addition, or where a bathroom has been added and it is unreasonable from an engineering or economic position to extend the existing heating system to the new area. Provide an occupant-activated time switch with a maximum time setting of 30 minutes for electric resistance or infrared heaters in family housing bathrooms. Family housing served exclusively by the Bonneville Power Authority (BPA) may use resistance heating in all rooms, provided a detailed engineering study has shown electric heating to be the most economical method on a life cycle cost basis, with demand charges fully accounted for. BPA has stated in writing that adequate power will be available for housing in the foreseeable future. Use thermostats with a maximum setting of 24 degrees C (75 degrees F) throughout the housing project.

(2) Small Remote Facilities. Electric resistance heating may be used where all of the following criteria are met:

- the individual facility (total building) heating load is less than 4 kW (15,000 Btu per hour) provided natural gas is not available within a reasonable distance;
- the facility has a maximum total energy consumption of less than 190 kilowatt-hrs per square meter (60,000 Btu per square foot) per year (nominal 40-hour week use) or less than 1,340,00 kJ per square meter (118,000 Btu per square foot) per year (around-the-clock use);
- the facility is equipped with thermostats with a maximum setting of 24 degrees C (75 degrees F) and a positive cutoff above 18 degrees C (65 degrees F) outdoor temperature; and
- all facilities occupied less than 168 hours per week must be equipped with a temperature setback to a maximum of 10 degrees C (50 degrees F) during all unoccupied periods. Small offices or duty stations located within larger unheated or partially heated buildings (e.g., warehouse office, dispatch office in a motor pool, duty room in an armory or reserve facility) requiring less than 4kW (15,000 Btu per hour) may use electric resistance heating under the conditions outlined above.

(3) Noncritical Fuel Areas. In geographical areas where at least 85 percent of the power is generated from noncritical sources such as hydroelectric, nuclear, or geothermal, electric resistance heating may be considered as an alternative in the life cycle cost analysis, provided energy budgets outlined in e(2) above are not exceeded and high-limit thermostats and setback controls are installed. Heat should be generated “off peak” through storage of low- or medium-temperature water and should be used directly or indirectly as a source for a water source heat pump or a combination of the above.

3-3. COOLING SYSTEMS.

a. Chilled Water. Determine the optimum supply and return water temperature differential by life cycle cost analysis.

b. Cooled Air. To the extent practical, minimize system airflow. Use integrated air conditioning and lighting systems whenever the general lighting level is 1000 lux (100 foot-candles) or greater.

3-4. COMFORT VENTILATION. Gravity ventilation is rarely adequate as a reliable source for comfort ventilation. It can be used in high-bay areas that are rarely occupied, such as storage buildings, or in areas that are difficult to ventilate, such as hangars. Consider nighttime air flushing of spaces, multi-speed fans, increased insulation, improved shading, and building site to improve the effectiveness of comfort ventilation. If a waiver to provide air conditioning in an area not authorized is submitted in accordance with paragraph 1-5, an hour-by-hour simulation of indoor conditions using comfort ventilation only will be included in the waiver request.

3-5. EVAPORATIVE COOLING. Use evaporative cooling where the facility in question is eligible for air conditioning, and evaporative cooling can provide the required indoor design conditions based on the appropriate outdoor design conditions. In many locations where evaporative cooling cannot provide the required indoor conditions year-round, give further consideration to its use as a supplement to the primary cooling system when preliminary life cycle calculations show the supplementary system to be cost effective. For special applications where close temperature or humidity control is required, consider two-stage evaporative cooling or indirect evaporative cooling in the life cycle cost analysis as a supplement to, not in lieu of, the primary cooling system.

3-6. COMBINATION HEATING-COOLING SYSTEMS. Combine heating-cooling systems to avoid duplication of system elements and to reduce costs.

a. All-air Systems. Where outdoor design temperatures are -6 degrees C (20 degrees F) or below, consider all air systems only in conjunction with double glazing, where sedentary activities are a minimum of 1 meter (3 feet) from the glass, and where proper peripheral air distribution is provided. Use preheat coils whenever the mixture of return air and ventilation air at outside design temperature is below 2 degrees C (35 degrees F).

b. All-water Systems. Use two-pipe dual-temperature systems for comfort applications where feasible. Four-pipe systems may be used where two-pipe systems are not capable of providing the specified indoor design conditions. Generally, three-pipe systems cannot be justified for comfort applications and will not be used.

c. Air-water Systems. Consider combinations of air and water systems such as radiant heating supplemented with single-zone interior air supply for ventilation; hydronic systems at the periphery of a building to offset skin transmission losses only, combined with the use of an air system for space cooling and ventilation loads.

d. Heat Pumps.

(1) When considering the use of heat pumps, a thorough engineering analysis is required. The designer must evaluate the requirement for possible additional power transmission and substation capacity, the added impact of demand charge power consumption, and peak demands.

(2) Select heat pumps (including air-to-air, ground source, etc.,) on the basis of life cycle cost effectiveness and include the following types, including combinations, where advantageous:

(a) ground source heat pumps, using wells or ponds as a heat source

(b) the perimeter spaces of a building must be heated and the interior cooled concurrently, water-to-air heat pumps utilizing a closed-water loop system air source heat pumps

e. Floor Radiant Heating Systems. Use hot water temperatures less than 50 degrees C (125 degrees F). Due to this low temperature, the designer will provide a control system to maintain the recommended water temperature for the boiler. Night setback control will not be used for high-mass floor systems. The designer will coordinate closely with the architect and structural engineer concerning floor insulation, floor coverings, floor load-bearing characteristics, and manifold access.

f. Radiant Heating and Cooling. Radiant heating and cooling systems are gaining wider acceptance among HVAC designers. The designer should carefully review the most current design guidance from both ASHRAE and manufacturers' literature prior to designing these systems, as they have many unique design characteristics.

3-7. DESSICANT DEHUMIDIFICATION. Both the ASHRAE Handbook Fundamentals and Handbook Applications describe several applications where desiccant dehumidification should be considered. These applications include instances where the latent load is large in comparison to the sensible load and instances where the energy costs to regenerate the desiccant is low relative to the energy costs required to dehumidify the air by chilling it below its dew point, missile assembly buildings, waveguide housings, and radomes.

3-8. THERMAL ENERGY STORAGE. Consider using thermal energy storage (TES) where, for example, it could reduce peak power demand charges, provide additional cooling capacity where it is more life cycle cost effective than adding cooling equipment, or provide life cycle cost effective redundancy necessary to ensure reliability for critical applications.

In many instances, utility deregulation is changing the cost structure of the power purchased by our customers. Subsidies for installing thermal energy storage and incentives for reducing the peak demand are not as prevalent as they were just a few years ago. It is imperative that the designers obtain the current utility rate structure and become knowledgeable about probable future utility costs so that accurate assumptions are used when determining the feasibility of using TES. Other factors of note include the unique methodology required to size a TES system, including both the hourly cooling load for the facility along with the hourly power consumption of the installation.

Where "ice-on-coil" is used as the method for TES, the loss in efficiency that occurs when chilling water to a lower design temperature must be factored into the life cycle cost analysis. This loss in efficiency may be somewhat offset by the lower temperature of the air entering the condenser during the hours when the system is "recharging." For facilities where a water tank is required, it may be advantageous to specify a tank suitable for storing chilled water. Regardless of the type of TES system specified, ensure that the supply water from the storage tank is at or below the required entering water temperature of all cooling coils during the last hour that the TES will be used at the outdoor design conditions specified.

CHAPTER 4

APPLICATIONS

4-1. GENERAL. The requirements pertaining to eligibility in this chapter are usually necessary to comply with the applicable energy budgets. If a customer requests a deviation for eligibility for air conditioning requirements, use the guidance in chapter 13 of Technical Instruction 800-01.

4-2. MIXED OCCUPANCIES. In those cases where a facility will have areas requiring both comfort conditions and areas requiring indoor design conditions that exceed the requirements for comfort (computer rooms, electronic rooms, etc.), use separate cooling system(s) for the areas requiring the more stringent conditions, or use system(s) that provide the comfort conditions with supplemental system(s) that provide required conditioning for the applications served. If, however, areas requiring comfort conditions require no more than 25 percent of the total cooling capacity or comprise no more than 100 square meters (1,000 square feet) of total floor space, the primary air-distribution system may be controlled to meet the more stringent conditions. Where reheat is required for areas requiring close control, the reheat capacity will be equal to the total design sensible heat generated within the area served.

4-3. ADMINISTRATIVE AREAS. Generally, administrative areas (including those in facilities that are not otherwise eligible for air conditioning, such as warehouses, shops, and hangars) will be air conditioned only in locations where the dry bulb temperature is 26.7 degrees C (80 degrees F) or higher for over 350 hours per year.

4-4. COMPUTER AND ELECTRONIC AREAS.

a. Computer Areas. Deviate from the indoor design conditions required for comfort conditioning, including temperature and humidity limits, only to the extent required to support the computers to be housed within the area. Other design considerations include the following:

(1) Where practical, use two or more smaller units to satisfy the required cooling capacity. This will generally reduce energy consumption at partial cooling loads and will also increase overall system reliability.

(2) Where an under-floor supply air plenum is used in conjunction with above ceiling return, base the number and size of outlets in the raised floor to deliver 80 percent of the total supply air. The remaining 20 percent of the supply air should be routed to the room via cable cutouts in the raised floor. Specify supply registers suitable for installation in floors on which it is anticipated that equipment will be moved. Locate ceiling return registers near heat producing equipment.

b. Electronic Equipment Areas (Communication, Surveillance or Research). Deviate from indoor design conditions for comfort cooling, including temperature, humidity, and level of filtration, only to the extent required to support the equipment housed within the area.

4-5. TOILETS, LOCKERS, AND UTILITY CLOSETS. Maintain these areas at a negative pressure relative to adjacent areas by exhausting air transferred from these adjacent areas to the outdoors. Where possible, the heating equipment capacity or energy consumption will not be increased by these areas.

4-6. VESTIBULES. Vestibules may be heated to 10 degrees C (50 degrees F) to melt tracked-in snow in locations where conditions warrant. Otherwise, vestibules will not be heated or air conditioned.

4-7. EQUIPMENT ROOMS.

a. Mechanical Ventilation. Equipment rooms will usually be ventilated using outside air intake louvers and a thermostatically controlled exhaust fan. Use a supply fan in lieu of an exhaust fan in rooms where atmospheric burners are located. The ventilation fan will have a two-speed motor, that is sized, at the high speed to have adequate capacity to limit the room dry bulb temperature to a maximum of 6 degrees C (10 degrees F) above the outdoor dry bulb temperature when both equipment and ambient loads are at their maximum peaks. The high speed will be activated 6 degrees C (10 degrees F) below the maximum temperature at which the most sensitive item of equipment in the room can operate. The low speed will operate at 11 degrees C (20 degrees F) below that of the high speed.

b. Air Conditioning. Air conditioning may be provided where life cycle cost effective to prevent severe corrosion in salt-laden areas where, during the six warmest consecutive months, the wet bulb temperature is 22.77 degrees C (73 degrees F) or higher for over 4,000 hours.

4-8. BATTERY ROOMS. Provide battery rooms with an exhaust fan interlocked with the battery charger so that the charger will not operate without ventilation. Size the exhaust fan to prevent hydrogen concentration in the room from exceeding 2 percent by volume. The power ventilation system for the battery room must be separate from ventilation for other spaces. Air recirculation in the battery room is prohibited. The fan motors must be outside the duct and battery room. Each blower will have a nonsparking fan. Consider using a multiple speed fan or multiple fans when the room is designed for two or more battery chargers. Size the exhaust fan as follows:

$Q = 0.025 \times I \times N$

where:

Q = Required ventilation rate in l/ sec.

I = 0.21 x (capacity of the largest battery to be charged in ampere-hours) or 0.25 x (the maximum obtainable amperes from the charger), whichever is greater.

N = (number of batteries to be recharged at one time) x (number of cells per battery). A single cell is normally 2 volts DC. Therefore, a 6-volt battery normally has 3 cells and a 12-volt battery normally has 6 cells. Areas used for battery storage in maintenance facilities will be ventilated at a minimum rate of 7.6 l/sec/m^2 (1.5 ft^3/min/ft^2), with care taken to ensure proper air distribution to and within the battery storage area.

4-9. KITCHENS AND DISHWASHING ROOMS.

a. Ventilation will be the chief means of preventing heat, odors, and smoke from entering dining areas and other adjacent spaces. Provide evaporative cooling where effective. Spot air conditioning or general air conditioning may be provided to keep temperature in the work areas from exceeding 29 degrees C (85 degrees F), if the main portion of the facility is air conditioned and the criteria for exhaust ventilation are met. Provide a separate ventilation system for the dishwashing area. Furnish tempered 18 degrees C db min (65 degrees F db min.) makeup air for the range hood exhaust. Do not recirculate more than 75 percent of air (excluding hood exhausts) in the kitchen at any time. Kitchen canopy hood exhaust ventilation rates will generally be 0.4 m/s (75 fpm) for grease filter sections, and 0.25 m/s (50 fpm) for open hood section, measured at the horizontal hood opening. As an alternative, internal baffle-type canopy hood with peripheral slot and a slot velocity of 2.5 m/s (500 fpm) is recommended. Use electrically interlocked supply and exhaust air fans and designed for 2-speed operation.

b. When substantial quantities of hot air exhausted from kitchen areas do not contain grease, consider using air-to-air heat exchangers in order to recover as much energy as possible. Evaluate the use of heat recovery in kitchens where heat rejected by refrigeration equipment is 15 kW (50,000 Btu/hr) or more.

c. Dishwasher room exhaust ducts will be as short as possible with direct runs to outside of building. Ductwork will have watertight joints and will have a drain line from the low point. Approximately 75 percent of the room air will be exhausted at the dishwasher, with the remainder exhausted at the ceiling. Dishwashers normally have duct collar connections so that exhaust ducts can be attached directly.

4-10. GYMNASIUMS, INDOOR COURTS, AND NATATORIUMS.

a. Enclosed handball and squash courts may be air conditioned. Generally, gymnasiums will not be air conditioned unless the dry bulb temperature exceeds 33.88 degrees C (93 degrees F) for over 1,300 hours and the wet bulb temperature is 22.77 degrees C (73 degrees F) or higher for over 800 hours, or the wet bulb temperature exceeds 22.77 degrees C (73 degrees F) for over 4,000 hours during the year. Where feasible, use transfer air from the gymnasium to condition the locker rooms thereby reducing energy consumption

b. Design natatoriums for year-round use. In order to conserve energy, the temperature of the air surrounding the pool should be as close as possible to the temperature of the water during the heating season. ASHRAE Handbook Applications addresses the many unique considerations that must be addressed when designing natatoriums.

4-11. LIVING QUARTERS.

a. Consider variable air volume system with individual room as an alternative to individual fan coil units for dormitory-type quarters in the life cycle cost analysis.

b. Provide air conditioning for the following types of facilities generally in locations where during the six warmest months of the year the dry bulb temperature is 26.66 degrees C (80 degrees F) or higher for over 650 hours or the wet bulb temperature is 19.44 degrees C (67 degrees F) or higher for over 800 hours:

(1) Fire Station Dormitories.

(2) Military Family Housing.

(3) Unaccompanied Enlisted Personnel Housing.

(4) Unaccompanied Officers' Personnel Housing.

(5) Temporary Lodging Facilities (including the Administrative Areas).

4-12. MAINTENANCE FACILITIES.

a. General Purpose Aircraft Hangars. Select heating systems on the basis of the outdoor design temperatures as presented in table 4-1. Floor-type unit heaters will introduce 20 percent outside air. Direct the discharged air to cover the entire floor area to break up explosive pockets. Provide motor-operated fresh air dampers for 100 percent outside air when desired. The capacity of heater fans will provide not less than six air changes per hour based on an artificial ceiling height of 5 meters (15 ft). In alert hangers, provide mechanical exhaust ventilation consisting of not less than 30 air changes per hour for control. In climates with winter design temperatures below -12 degrees C (10 degrees F) or where annual snowfall exceeds 50 cm (20 inches), provide snow-melting coils circulating heated antifreeze solution under hangar door tracks.

Table 4-1. Heating System—Hangars.

Outside design temperature degrees C db (degree. F db)	System Type
-18 degrees C (0 degrees F) and below	Radiant heating will be installed in the floor slab of the hangar area to provide 50% of the requirement, supplemented by floor-type air-handling units.
Between -17 degrees C and 4 degrees C (1 degree F and 40 degrees F).	Floor-type air-handling units will be provided. Overhead and unfired unit heaters may be used to supplement floor-type heaters where hangar width is greater than 45 meters (150 ft).
Above 4 degrees C (40 degrees F).	None required.

Note: Floor-type air-handling units will be arranged to draw warm air from the top of the hangar for distribution at occupied level.

b. Aircraft Maintenance Shops (Avionics). Where effective, evaporative cooling may be used. Provide air conditioning for those functional areas where required for quality control of equipment, material, and task. In all cases, localized or spot air conditioning may be provided at individual workstations; however, the entire shop area will not be air-conditioned.

4-13. STORAGE FACILITIES.

a. General Purpose Warehouses. Do not heat warehouses used to store materials not subject to freezing. For warehouses containing materials subject to freezing, design heating systems to maintain an inside winter temperature of 4 degrees C (40 degrees F). In warehouse areas with active employment, temperatures of 13 degrees C (55 degrees F) will be maintained. Consider both unit heaters and radiant heaters as alternatives in the life cycle cost analysis. Evaporative cooling may be provided in active warehouses where effective.

b. Dehumidified Warehouse.

(1) Where only humidity control is required, the life cycle cost analysis will compare dry desiccant-type dehumidifier and refrigerated dehumidification. The dry desiccant type will consist of two stationary beds or will be the rotary type with operation alternating between drying and refrigeration.

(2) Where both temperature and humidity control are required, use a central air conditioning system.

4-14. LABORATORIES.

a. Design HVAC systems to provide control over space temperature conditions including contaminants and fume control appropriate to the space function. Provide exhaust systems with fume hoods to remove toxic substances as near to the source of the fumes as practical. Hood and system design will follow the recommendations of the American Conference of Government Industrial Hygienists Manual. Base minimum design face velocities for hoods on the toxicity of the material being handled. Face velocities at the hood opening should be as follows: highly toxic substances at 0.65 m/s (125 fpm), general laboratory exhaust at 0.45 m/s (80 fpm), and non-toxic substances at .025 m/s (5 fpm).

b. Base the amount of supply air on the room-cooling load and all exhaust requirements. Locate supply air intakes with care to avoid cross contamination with exhaust air discharges. Design air supply, exhaust and automatic control systems to provide flexibility for potential changes in the use of space.

4-15. HOSPITALS. HVAC designs for hospitals will be in accordance with Military Handbook 1191.

4-16. COMMISSARIES. HVAC designs for commissaries will be in accordance with the AEI.

4-17. LAUNDRIES AND DRY CLEANERS. Mechanical ventilation will generally be the primary method of heat dissipation. Evaporative cooling may be provided where effective. Spot air conditioning or general air conditioning may be provided to keep the temperature in the work areas from exceeding 29 degrees C (85 degrees F). Coil discharge temperatures used in spot cooling should be 10 degrees C (50 degrees F) dry bulb maximum for maximum dehumidification. Where feasible, use heat recovery equipment on exhaust air to temper makeup air in cold weather. Design clothes dryer exhaust venting in accordance with ETL 1110-3-483, Clothes Dryer Exhaust Venting.

4-18. RESERVE CENTERS. Typically, only a small portion of a reserve center is occupied during normal working hours, while the balance of the facility is used primarily for weekends only. Consider the anticipated occupancy pattern when developing equipment layout and sequence of operation in order to ensure that overall life cycle cost is minimized.

4-19. ARTS AND CRAFTS/SKILL DEVELOPMENT CENTERS. These facilities may be air conditioned provided the functions require ventilation rates beyond that based on the number of occupants only (such as metal and woodworking shops) or where excessive heat releases are generated by equipment housed in the facility (such as kilns and welding equipment).

4-20. OTHER ELIGIBILITY CRITERIA.

a. Provide air conditioning for the following facilities only in locations where the dry bulb temperature is 26.66 degrees C (80 degrees F) or higher for over 650 hours or the wet bulb temperature is 19.44 degrees C (67 degrees F) or higher for over 800 hours during the six warmest months of the year:

(1) Auditoriums and Theatres.
(2) Banks.
(3) Bowling Alleys.
(4) Chapels.
(5) Daycare Centers, Schools, and Libraries.
(6) Stores and Exchanges.
(7) Clubs and Dining Facilities.
(8) Post Offices.
(9) Indoor Target Ranges.

b. The following types of facilities are not eligible for air conditioning regardless of weather conditions:

(1) Boiler Plants.
(2) Greenhouses.

CHAPTER 5

EQUIPMENT

5-1. LOCATION OF EQUIPMENT. Specify air-conditioning equipment, including air handlers, compressors, pumps and associated equipment that is suitable for outdoor installation where life cycle cost effective. When comparing interior and exterior equipment installations in life cycle cost analysis, include all associated building costs required to house interior equipment in the analysis. Provide details on the drawings necessary to ensure drainage for “winterizing” equipment where appropriate.

5-2. CHILLERS. Individual reciprocating machines will not exceed 700kW (200 tons) capacity, and the total capacity of all reciprocating machines or packaged air-conditioning units equipped with reciprocating compressor used for air conditioning a single facility will not exceed 1400kW (400 tons). A single packaged unit will not contain more than eight compressors. Where multiple chillers are specified, provide a chilled water pump and a condenser pump for each chiller. With the exception of the criteria listed herein, the number of chillers specified will be optimized in the life cycle cost analysis. Where there is a combination of normal summer air-conditioning loads and year-round air-conditioning loads optimize system zones and size system components to support the entire facility load during warm weather and a portion of the equipment may be essentially fully loaded during winter operations. In facilities when, because of the small size of the off-hours or the small winter load, it is impractical to operate the primary equipment in the central plant, an auxiliary refrigeration system may be provided. Use heat recovery where it is life cycle cost effective.

a. Reciprocating Compressors.

(1) For chillers over 35 kW (10 tons), use capacity control which reduces the power requirement as the load varies.

(2) Compressors operating in parallel will have the normal oil level at the same elevation for all machines and the crankcases of these compressors will be provided with gas and oil equalizing lines. When compressors are connected in parallel, arrange the hot-gas discharge lines so that the oil from the common discharge line will not collect in an idle unit while the other units are running, and size the lines to provide an equal pressure drop between each machine and its respective condenser. The suction lines will return refrigerant gas and oil from the evaporator to the compressor during operation of the system, and will not allow oil or liquid refrigerant to be returned as slugs at any time. Provide means for trapping oil in the common suction header to prevent oil slugs from collecting in the idle compressor.

b. Centrifugal Compressors. When a two-stage centrifugal compressor is selected, a refrigerant intercooler will also be required. For low-temperature applications, where compressors with four or more stages may be needed, two-stage intercoolers will be used. Use capacity control methods to reduce energy consumption as the load is reduced to minimize life cycle costs.

c. Helical Rotary (Screw) Compressor. Screw compressors will use oil injection. An oil separator or sump and oil cooler will be included in the system. Oil coolers assist the condenser in rejecting heat, so the refrigerant condenser can be reduced in capacity equal to the amount of heat extracted by the oil cooler.

d. Electrical and Mechanical Drives. Base the choice of drives for refrigeration equipment on the availability and price of fuel, cost of electricity, or the capability of using waste heat. The operating characteristics of the refrigeration compressor are typically a major factor in determining the compatibility of the drive and compressor.

(1) In areas of high electric demand rates, evaluate the impact of air conditioning of the facilities' peak electric demand to determine economic feasibility of electric drive. Compare this to the cost per kWh, installation peak load, and any demand charges or incentives provided by the utility serving the installation. Deregulation in the electric utility industry may change the cost structure paid by the installation, so take into account any known or potential changes that may result from deregulation.

(2) Where steam turbine drives are used, evaluate using the exhaust steam of non-condensing turbines as the input to low pressure steam absorption refrigeration in the life cycle cost analysis.

(3) Use only split-shaft gas turbines for air conditioning due to the poor starting characteristics of single-shaft machines. Whenever gas turbines are used, evaluate using exhaust gases to generate steam in a waste heat boiler to power absorption refrigeration in the life cycle cost analysis.

e. Absorption Refrigeration.

(1) Consider absorption equipment only where waste steam from incineration of solid wastes, heat recovery engine or gas turbine exhausts, or exhaust from steam turbine drives for refrigeration compressors or electric generators are available.

(2) Absorption chillers must have the capability of operating at variable condenser water temperature without crystallization.

(3) Use a throttling valve to modulate flow to the absorbent generator with chilled water temperature, as well as an automatic steam valve which reduces steam pressure and temperature, for energy efficient part load capacity control.

(4) Consider using two-stage absorption refrigeration whenever high-pressure steam or high-temperature water is available. The life cycle cost analysis will address the economic feasibility of using the higher first-cost, two-stage machine.

5-3. BOILERS. This paragraph provides criteria for gas- and oil-fired low-temperature hot water boilers and low-pressure steam boilers that are used primarily for single building applications. Central heating plants will be in accordance with TM 5-815-1.

a. Boiler Types.

(1) Cast iron boilers are available in sizes up to 3800 kW (13,000 MBtuh or1.3×10^7 Btuh) gross output. Advantages include low maintenance and sectional construction.

(2) Steel firebox boilers may be of a fire tube or water tube design. A principal advantage is the capability of interchanging fuels such as coal for oil or gas if necessary. Capacities up to 6900kW (23,500 MBtuh) gross output are available.

(3) Whenever the fuel choice is either gas or oil and there is no likelihood of converting to coal, package boilers may be installed. Package boilers are either of a fire tube (including Scotch marine) or water tube design.

b. Multiple Boiler Installations.

(1) Provide adequate room, connections, piping, etc., in boiler installations where future expansion is likely. Boilers and related auxiliaries used for future loads can be added as necessary.

(2) Determine the number and size of boilers to efficiently serve both the maximum winter design load and the minimum summer load. With the largest boiler off line, the remaining boiler(s) will be capable of carrying not less than 65 percent of the maximum winter design load. Where the smallest boiler installed has a capacity of more than twice the minimum summer load, consider adding an additional boiler or hot water heater sizes for the anticipated summer load.

c. Steam Boiler Accessories. Provide a chemical feed system in accordance with TM 5-650 based on an analysis of the makeup water to be used. Depending upon the size of the installation and the pressure at which steam is generated, use boiler accessories such as feedwater heaters to increase the steam generation cycle efficiency where applicable.

d. Feedwater Heating Systems.

(1) Install heaters for the de-aeration of feedwater for ***all installations*** with steam capacities in excess of 6,000kW (20,000 MBtuh). This should be considered for installations of 4,500 kW (15,000 MBtuh) to 6,000 kW (20,000 MBtuh) capacity where estimated makeup rates are 15 percent or more or where the plant serves a number of buildings. Installations operating with either hot lime-soda or hot lime plus hot sodium zeolite softeners incorporating provisions for the de-aeration of the treated water and condensate separately require no additional de-aeration.

(2) Provide steel surge tanks for the storage of condensate. Install the surge tanks upstream of the feedwater heaters where the space-heating load predominates, where large quantities of condensate are returned by condensate pumps, and where steam-driven auxiliaries are used. Size surge tanks to provide 20 minutes of condensate storage based on boiler steaming capacity.

(3) Feedwater flow rate to the heater should equal the boiler demand. Size feedwater pumps 10 percent larger than the capacity calculated to allow for pump cooling requirements.

(4) Install feedwater heaters above the boiler feed pump suction at a height sufficient to prevent flashing at the pump inlet at the design feedwater temperature. With a feedwater temperature of 100 degrees C (212 degrees F) and a back pressure on the feedwater heater of approximately 14 kPa (2 psi), the hydrostatic head on the feed pumps should be approximately 3 meters (10 feet). Where the boiler feed operates at temperatures above100 degrees C (212 degrees F), increase the hydrostatic head in proportion to the increase in the vapor pressure of the liquid. Provide a bypass and isolation valves for each feedwater heater to permit operation of the boilers at times when the heater is being serviced.

c. Combustion Equipment. The installation of combustion equipment, including burners and draft fans, will be in accordance with ASHRAE Handbooks, Underwriters Laboratory (UL), National Fire Protection Association (NFPA), and the recommendations of equipment manufacturers.

(1) Gas Burners. All gas-fired equipment will be equipped with a burner, which can be readily converted to burn an alternate fuel, as required in AR 420-49. Specify gas equipment for dual-fuel capability.

(2) Oil Burners. The selection of oil burners will depend on the grade of the oil being burned, the size of installation, and the need for modulating control. For light oil, atomizing will be accomplished using oil pressure, air, or steam atomizing burners. For heavy oil, atomizing will be accomplished using air or steam atomizing burners.

(3) Stacks and Draft Requirements. Heating installations will include either natural-draft chimneys or individual boiler ventilation fans with stub stacks. Where natural-draft stacks would be a hazard to aircraft or otherwise objectionable, use mechanical-draft fans discharging into short stub stacks.

f. Fuel Selection and System Design. Fuel selection and system design will be in accordance with the AEI, ASHRAE Handbooks, NFPA Standards, Military Handbook 1008, and AR 420-49.

g. Auxiliaries. Where required, request for standby electric generators will be in accordance with paragraph 1-5. Boiler plant auxiliaries should, in general, be electrically driven; however, whenever an uninterrupted supply of steam is essential, provide one of the boilers with steam-driven auxiliaries. Provide individual forced and/or induced-draft fans with each boiler unit. Provide necessary standby equipment to maintain essential operations.

h. Flow Measurement.

(1) Provide gas and oil meters for the boiler installation. Provide a gas meter at each building. Install oil meters in both the supply line and the return line of each storage tank.

(2) Meter all building steam supply, hot water supply, condensate return, and hot water return lines.

APPENDIX A

REFERENCES

GOVERNMENT PUBLICATIONS

Department of Defense

Military Handbook 1008C	Fire Protection For Facilities Engineering, Design, and Construction

Department of the Army

AR 420-49	Utility Services
TM 5-650	Central Boiler Plants
TM 5-785	Engineering, Weather Data
TM 5-805-4	Noise and Vibration Control for Mechanical Equipment
TM 5-805-6	Joint Sealing for Buildings
TM 5-809-10	Seismic Design For Buildings
TM 5-815-1	Air Pollution Control Systems for Boilers and Incinerators
TM 5-815-3	Heating, Ventilating, and Air Conditioning Control Systems
TM 5-838-2	Army Health Facility Design

Army Corps of Engineers

TI	Technical Instruction 800-01, Design Criteria

NONGOVERNMENT PUBLICATIONS

American Conference of Governmental Industrial Hygienists, 650 Glenway Ave.,

Bldg. D-7, Cincinnati, OH 45211

Industrial Hygienists Manual American Society of Heating, Refrigerating and Air Conditioning Engineers, Publication Sales, 1791Tullie Circle, NE, Atlanta, GA 30329-2305

Handbook	Equipment
Handbook	Fundamentals
Handbook	Refrigeration
Handbook	HVAC Systems and Applications
Guideline 3	Reducing Emission of Fully Halogenated Chloro-fluorocarbon (CFC) Refrigerants in Refrigeration and Air Conditioning Equipment and Applications
Standard 52	Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
Standard 62	Ventilation for Acceptable Indoor Air Quality